Clinical Trials for the Treatment of Secondary Wasting and Cachexia

Body Composition: Overview[1,2]

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ABSTRACT The following is a listing of body composition techniques now available, together with a brief description of the underlying assumptions and the advantages and disadvantages of each. J. Nutr. 129: 270S–272S, 1999.

KEY WORDS: • *body composition* • *body density*

A product largely of the current century, modern body composition techniques provide for the partition of the human body, in a non-traumatic way, into various components; in a manner of speaking, a bloodless dissection. However, the foundation for their use was established earlier, as an offshoot of the 19th century chemists' inquiries into the nature of living things. It was early recognized that young organisms had a higher water content and a lower ash content than the adult. Then Claude Bernard was to announce the concept of "la fixitié du milieu intérieur" as a necessary feature for a free and independent life. By the end of the 19th century a number of fetuses and newborns had been analyzed for Na, K, Cl, Ca, P and N, as well as water and fat. Similar analysis in adults did not come until much later. Figure 1 shows the sequence of events in schematic form.

An important conceptual advance came from Adolf Magnus-Levy, who announced in 1906 that tissue composition is best expressed on a fat-free basis, and so was borne the concept of the fat-free body mass, on which several of the modern body composition techniques are based.

The passing years have witnessed a proliferation of body composition techniques, with the result that we now have a lot of information on its various aspects from infancy through old age. In the tables to follow these will be considered under several categories.

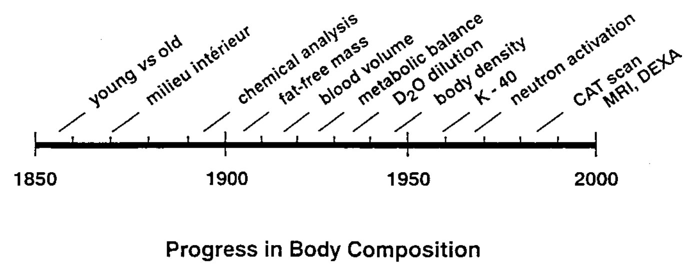

FIGURE 1 Schema of progress in body composition principles and techniques during the last century and a half.

We begin with the two-component model, in which the body is divided into lean and fat. The assumption is that the lean body mass, also known as the fat-free mass, has a rather constant composition in mature subjects. Hence by determining the amount of a given constituent, such as water, potassium, or nitrogen present in the body, the magnitude of the fat-free mass (FFM)[4] can easily be calculated. Total body water is determined by isotope dilution (D_2O, tritium, or ^{18}O), total body potassium by assay of ^{40}K, a natural isotope, and total body nitrogen by neutron activation. Body fat is then the difference between body weight and FFM. It has been empirically determined that urinary creatinine excretion and the resistance of the body to a very weak alternating current (bioelectrical impedance) both bear a relationship to the FFM.

Measurement of body density—either by underwater weighing or on land by applying Boyle's law—provides an estimate of both FFM and body fat, the assumption being that the FFM in mature subjects has a constant density.

Nitrogen balance, by which is meant the intake of N via diet or infusion minus excretion in urine and feces, can be used to estimate changes in FFM. Anthropometry uses a different approach in aiming at an estimate of body fat, where FFM is

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[4] Abbreviations used: FFM, fat free mass; DEXA, dual-energy x-ray absortiometry; LBM, lean body mass; BIA, bioelectrical impedance.

TABLE 1

Two component models

Technique	Advantages	Disadvantages
Total body water	Little cooperation needed	^{18}O isotope expensive, tritium is radioactive
Body density	Land-based technique Easy and quick *	Underwater weighing difficult in some subjects
Total body potassium	Almost all body K is in ICF	Apparatus expensive, proper calibration required
Total body nitrogen	Almost all body N is in ICF	Apparatus expensive, proper calibration required, some radiation exposure
Nitrogen balance	Small changes detectable	High degree of cooperation, many laboratory analyses needed
Urinary creatinine excretion		Cooperation needed, influenced by diet
Bioelectrical impedance	Easy, quick	Many formulas, poor precision for estimating changes in FFM**
Anthropometry	Easy, inexpensive	Uncertainty ratio s.c. fat/total body fat

* McCrory et al. (1995); Dempster and Aitkens (1995)
** Forbes et al. (1992); Yanovski et al. (1996)

TABLE 2

Multi-component models

Techniques	Advantages	Disadvantages
Dual-energy x-ray absorptiometry (DEXA)*	Estimate of soft tissue, lean tissue, bone and fat	Apparatus expensive radiation exposure
CAT scan	Delineates organ size, fat and muscle distribution, bone size	Instrument expensive radiation exposure
Magnetic Resonance Imaging (MRI)	Delineates organ size, muscle, fat, fat distribution, total body water	Apparatus very expensive
Seratim application of several techniques**	Provides values for total body fat, water, protein and minerals	Much apparatus needed

* Pietrobelli, et al. (1996)
** Heymsfield, et al. (1996)

gotten by subtraction. It principally involves the measurement of the thickness of skin plus subcutaneous fat by means of special calipers (or even by ultrasound). The assumption is that the amount of subcutaneous fat, in the sites chosen for measurement, is proportional to total body fat. Combining skin fold measurements with body weight and certain body circumferences leads to a better estimate of total body fat. Table 1 lists the advantages and disadvantages of each of the above techniques.

We next consider multi-component models of body composition (Table 2). These have been developed in recent years in order to provide estimates of the various components of the fat-free mass, as well as the distribution of the adipose organ. They can be useful in situations where it is likely that the composition of the fat-free mass is altered, so that the simple two-component model cannot be applied.

Of the items listed in Table 2, dual-energy x-ray absorptiometry (DEXA) has found the widest use. While expensive, it is much less so than either the CAT scan or MRI, and the radiation dose is very small, actually less than one receives from a high altitude transcontinental air flight.

The most cumbersome procedure is the last one in Table 2. Various combinations have been used: total body water, total body nitrogen, and total body calcium is one example. It is obvious that this technique is very demanding of equipment and talent, and there are only a few research laboratories capable of carrying out such an array of procedures.

Table 3 lists some additional techniques of interest. Body fluid volumes are relatively easy to measure, as is total erythrocyte mass. Total exchangeable sodium and potassium require that radioactive isotopes be given, while total body chloride can be approximated by bromide dilution.

Elemental analysis is performed by total body neutron activation, a procedure requiring elaborate instrumentation and a small amount of radiation.

Metabolic balance can detect *changes* in body content of a number of elements. It cannot estimate total body content per se. It consists of measuring input (food, drink) and output (urine, feces) of the element in question; and while the procedure is very demanding of both investigator and subject (the latter must be most cooperative and compliant) it is capable of estimating changes in body composition with much better precision than any of the other techniques listed here. Moreover, it can be used to study elements such as Se, Pb, and Hg, which cannot be measured by the other techniques.

Recently I had occasion to be measured by several techniques over a rather brief span of time, and the resultant estimates of my lean body mass (LBM) are listed in Table 4. Incidentally, I am 81 years old, weighing 80 kg, and am 178 cm tall. As can readily be seen, the first eight assays listed pro-

TABLE 3

Other techniques

Body fluid compartments—plasma volume, ECF volume, total body water, ICF volume (by difference), erythrocyte mass
Total exchangeable Na, K; total body Cl
Elemental analysis by neutron activation: Na, Cl, P, Ca, N
Metabolic balance—many elements (change in body content only)

TABLE 4

Author's LBM by various techniques

Assay	LBM, kg	Location
K-40	49.7	Rochester
K-40	48.8	N.Y.C.
THO Dilution	50.5	N.Y.C.
Density (under-water weighing)	49.4	N.Y.C.
Density ("Bod-Pod")	49.5	Buffalo*
DEXA	49.1	N.Y.C.
DEXA	49.1	Rochester
Skinfolds, circumferences	48.6	N.Y.C.
BIA	59.2	Rochester
BIA	56.4	N.Y.C.

N.Y.C. refers to St. Luke's Hospital Obesity Research Center, Drs. Richard Pierson, Jack Wang, and Steven Heymsfield.

* Courtesy Mr. John Torine, trainer Buffalo Bills team. The "Bod-Pod" is a new device for measuring body volume on land, by application of Boyle's law.

duced almost the same result, the mean being 49.3 kg, SD 0.6 kg (c.v. 1.2%). This sort of variability is what would be expected from repeated assays on a single subject by any one of these techniques.

The one aberrant value was generated by bioelectrical impedance (BIA) (arm-leg configuration, single frequency). Although this technique is widely used, it does not accurately reflect changes in body composition induced by diet or exercise (Forbes et al. 1992), and a disturbing feature is that the theoretical basis for the procedure is unclear (Yanovski et al. 1996).

There are a number of other techniques (see Forbes 1987, Roche et al. 1996) which have found very limited use. These books should be consulted for details and fuller exposition of the various techniques listed in the tables. It is obvious that the investigator now has a number of techniques at his/her disposal for making estimates of body composition in living subjects.

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